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IMPACT OF ANTECEDENT RUNOFF CONDITION ON CURVE NUMBER DETERMINATION AND PERFORMANCE OF SCS-CN MODEL FOROZAT CATCHMENT IN INDIA

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ABSTRACT

The Soil Conservation Service Curve Number (SCS-CN) is a well-established technique among the engineers to estimate runoff. It combines watershed and climatic parameters in one entity curve number (CN).Much of the variability in CN has been attributed to antecedent runoff condition (ARC). The wetter soils have a higher CN, creating more runoff for a given amount of precipitation, than the drier soils.In the present study, an attempt has been made to determine the CN by three procedures, viz, the median, geometric mean and standard asymptotic fit using gauged rainfall and runoff and five days ARC with an objective to evaluate the influence of five days ARC on performance of SCS-CN method for Ozat catchment of India. All these methods were tested with initial abstraction ratios (λ=0.05, λ=0.1 and λ= 0.2). Refined Willmott's index (d_r) and mean absolute error (MAE) were used to assess the simulated performance of each method. The results indicate that the performance of SCS-CN method is improved on application of five days ARC. For the study area, the SCS-CN method with CNs determined by asymptotic fit method and five days ARC data set was judged to be more consistent with d_r=0.58 and MAE=0.93 mm.

KEYWORDS: Soil Conservation Service Curve Number (SCS-CN) Method, Curve Number, Antecedent Rainfall, Ozat Catchment

INTRODUCTION

The Natural Resources Conservation Service (NRCS) curve number (CN) procedure is widely used to estimate runoff resulting from rainstorms. It is based on the parameter CN, a lumped expression of basin absorption and runoff potential and the parameter I_a (initial abstraction) that represents the interception, the infiltration and surface depression during the early part of a storm. This method originally developed from daily rainfall data from small agricultural watersheds in the Midwestern United States (Mockus 1949; Rallison 1980) and it was first introduced in 1954 (NRCS 2001). The primary reason for its wide applicability and acceptability lies in the fact that it accounts for major runoff-generating watershed characteristics, namely, soil type, land use/treatment, surface condition and antecedent moisture condition (Mishra and Singh 2002; Mishra and Singh 2003 a; Ponce and Hawkins 1996). In contrast, the main weaknesses reported in the literature are that the SCS-CN method does not consider the impact of rainfall intensity, it does not address the effects of spatial scale, it is highly sensitive to changes in values of its single parameter, CN, and it is ambiguous considering the effect of antecedent moisture conditions (Hawkins 1993; McCuen 2002; Michel et al. 2005; Ponce and Hawkins 1996). Nevertheless, the model development has made much progress in last three decades; a need of further improvements has always been experienced to satisfy unresolved challenges.

After the critical examination of the methodology by (Ponce and Hawkins 1996), the SCS-CN method has gained much attention with respect to its modification and investigation. Subsequent studies (e.g. King et al. 1999; Jacobs et al. 2003; Garen and Moore 2005; Michel et al. 2005; McCutcheon et al. 2006) examined the accuracy of the curve number method and identify specific weaknesses and limitations that are not widely recognized and that are rarely noted in textbooks. A chief limitation is the failure to account for the temporal variation in rainfall and runoff (Ponce and Hawkins 1996; King et al. 1999). Recent modifications in determination of curve number are reported by slope adjustment procedure (Sharpley and Williams 1999), two-CN system approach (Soulis and Valiantzas 2012) and composite CN-generation (Fan et al. 2013). The method acknowledges observed CN (or runoff) variation between events based on basin factors, originally explained as Antecedent Moisture Condition (AMC), with three classes (I, II, III) defined on 5-day prior or antecedent rainfall. This 5-day rainfall approach is no longer endorsed by NRCS, and the approach has been generalized to Antecedent Runoff Condition (ARC). A probabilistic interpretation to cover all sources of variation –including prior site moisture - has been offered. The ARC II status is accepted as the reference condition and is the basis for CN handbook tables. This study compared CNs determined by three procedures using gaged daily rainfall-runoffdata set and five days ARC data set. These procedures include the median (NRCS 2001), geometric mean (NRCS 2001), and standard asymptotic fit (Sneller 1985; Hawkins 1993). The performance of SCS-CN method with CNs determined based on five days ARC is also evaluated for selected catchment.

The objectives of this study were: (1) to compare CNs determined by gauged daily rainfall-runoff and five days ARC using the median, geometric mean and standard asymptotic fit procedures; and (2) to evaluate the impact of five days ARC CNs on performance of SCS-CN method for Ozat catchment.

MATERIALS AND METHODOLOGY

Study Area and Data Collection

Ozat is a river flowing in western India in Gujarat state whose origin is near Visavadar and meets in Arebian Sea. Ozat is third largest river of Saurashtra region after Bhadar and Shetrunji rivers. Ozat catchment considered in this study geographically locates within the latitudes $21^0 19^{'}$N to $21^0 33^{'}$N and the longitudes $70^0 39^{'}$E to $70^0 56^{'}$E respectively as can be seen from toposheet no 41K (10-11-14 and 15) of scale 1:50000. The gauge discharge site is located near Khambhaliya village at bridge of Junagadh to Visavadar Road 33 km away from Junagadh. Information about soil and land use have been gathered from maps of National Bureau of Soil Survey and Land use Planning (ICAR) (1994). Study area (sub-watershed) has been delineated from Survey of India (SOI) topographic sheet using AutoCAD (2010) Software (Figure 1). The major portion of the precipitation occurs during the four months of June to September by south-west monsoon. The study area has three pronounced seasons, the monsoon season of mid-June to early October; the dry winter season, which follows through until February and the hot dry season from March to mid-June. The area is situated in semi-arid region with average annual rainfall of the area is 786 mm (1980-2010), mean maximum temperature 33.34^0C and mean minimum temperature 24.30^0C. The area has the high annual variability of rainfall from 211 to 2216 mm. It is characterized by erratic rainfall pattern. The total geographical area 358.8357 Sq. Km. comprises of about 20.08% (72.0542 Sq. Km.) grass and open scrub land and remaining 79.92% area under arable land irrigated (286.7815 Sq. Km.). The major crops grown in the catchment are Ground nut, wheat and Cotton.

The hydrological data daily rainfall (mm) and runoff (m^3/s) (1980 to 2010) and meteorological data daily maximum and minimum temperatures of Ozat catchment were collected from the State Water Data Centre, Gandhinagar.

The information related to watershed characteristics, namely, physiography, number of streams of different orders, their length, slope and area contributing runoff to these streams were obtained from the topographic maps of the watershed.

Periodic insufficient rainfall pattern, limited water storage capacity of aquifer and natural water conservation are vitalissues for this region. Water availability is a critical factor in this area and therefore accurate estimation of runoff is needed for water resources management, crop water use, farm irrigation scheduling, and environmental assessment.

SCS-CN Method

One of the most commonly used methods to estimate the volume of surface runoff for a given rainfall event is the Soil Conservation Service Curve Number (SCS-CN) method (SCS 1956, 1964, 1971, 1993), which has been now renamed as Natural Resource Conservation Service Curve Number (NRCS-CN) method. The SCS-CN method is based on the principle of the water balance and two fundamental hypotheses (Mishra and Singh 2002). The first hypothesis states that the ratio of direct runoff to potential maximum runoff is equal to the ratio of infiltration to potential maximum retention. The second hypothesis states that the initial abstraction is proportional to the potential maximum retention. The water balance equation and the two hypotheses are expressed mathematically respectively, as:

$$P = I_a + F + Q \qquad (01)$$

$$\frac{Q}{P - I_a} = \frac{F}{S} \qquad (02)$$

$$I_a = \lambda S \qquad (03)$$

Where P is the total precipitation (mm), $I_a$is the initial abstraction before runoff (mm), F is the cumulative infiltration after runoff begins (mm), Q is direct runoff (mm), S is the potential maximum retention (mm), and λ is the initial abstraction (ratio) coefficient.

In larger sized basins, some rainfall will fall directly on surface water or riparian areas with an immediate (albeit small) response in the mainstream hydrograph. Small amount of rainfall events result in even smaller changes in runoff that can sometimes be difficult to discern in the discharge time series. To minimize uncertainty in the determination of the storm event discharge, storms events with $P_5 \geq 5$ mm have been considered to determine CN values in calibration period for this study. In simulation period all events have been considered to measure the performance of SCS-CN method.

The λ was assumed to be equal to 0.2 in original SCS-CN model. In order to simplify the equation and eliminate one variable ($\lambda = 0.2$), I_a is fixed at $I_a = 0.2S$ (Ponce and Hawkins 1996; Young 2006). However, the assumption of $\lambda = 0.2$ has frequently been questioned for its validity and applicability, invoking a critical examination of the $I_a - S$ relationship for pragmatic applications (Ponce and Hawkins 1996; Baltas et al. 2007). A study using rainfall and runoff data from 307 US catchments or plots found that a value of $\lambda = 0.05$ would fit the data much better (Woodward et al. 2003). (Fu et al. 2011) found that the prediction accuracy for $\lambda = 0.05$ was greater than that for $\lambda = 0.2$ using SCS-CN method to simulate plot runoff of 757 rainfall events in Zizhou and Xifeng cities located in the Loess Plateau of China. Similar results have been obtained from plots or watersheds in USA (Hawkins et al. 2002), semi-arid tropical highlands of Northern Ethiopia (Descheemaeker et al. 2008) and the Three Gorges area of China (Shi et al. 2009). The assumption $\lambda = 0.2$ has been recently considered unusually high and recent studies (Hawkins et al. 2009; D'Asaro and Grillone 2010, 2012) suggested

the use of λ = 0.05. In the present study simulated performance of all the methods were compared and tested with λ = 0.05, λ = 0.1 and λ = 0.2.

The general runoff equation combination of Eq. (01) and Eq. (02) introduced by the (SCS-NRCS 1964, 1972, 1985 and 2004) is shown in Eq. (04):

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \text{ for } P > I_a$$

$$= 0 \text{ otherwise} \tag{04}$$

The potential maximum retention S (mm) can vary in the range of $0 \leq S \leq \infty$, and it directly linked to a dimensionless coefficient called “Curve Number” (CN). Parameter S is mapped to the CN using Eq. (04) as:

$$S = \frac{25400}{CN} - 254 \tag{05}$$

The CN depends on land use, hydrologic soil group, hydrologic condition, antecedent moisture condition (AMC) (SCS 1971) and it can vary from 0 to 100. Three AMCs were defined as dry (lower limit of moisture or upper limit of S), moderate (normal or average soil moisture condition), and wet (upper limit of moisture or lower limit of S), and denoted as AMC I, AMC II, and AMC III, respectively (Mishra and Singh 2003). The higher the antecedent moisture or rainfall amount, the higher is the CN and, therefore, the high runoff potential of the watershed and vice versa. For CN determination, an array of CN-values from various rainfall-runoff (P-Q) data sets is prepared, and median CN selected as a representative CN valid for normal antecedent moisture condition of the watershed. This ‘Median CN’ approach is commonly adopted (Hawkins et al. 1985; Hjelmfelt 1991; Hawkins et al. 2002; Schneider and McCuen 2005; and Mishra et al. 2005).

Normally variations in storm characteristics and surface conditions can responsible for variation in CN between events. (Ponce and Hawkins 1996) reported as possible sources of CN variability the effect of the temporal and spatial variability of storm and watershed properties, the quality of the measured data, and the effect of antecedent rainfall and associated soil moisture. (Soulis et al. 2009) and (Steenhuis et al. 1995) also noted that the variation of CN value, according to AMC category alone, cannot justify the observed CN values variability in every case. Much of the variability in CN has been attributed to antecedent runoff content such that soils that are wetter have a higher curve number, creating more runoff for a given amount of precipitation, than soils that are drier (Huang et al. 2007; Shaw and Walter 2009). Many researchers have demonstrated from rainfall and runoff data that its key parameter CN has variable components and is not a constant for a watershed (Hjelmfelt et al. 1982; McCuen 2002), and varies with rainfall. Building on elements of this previous work, we compare CNs determined bydaily rainfall-runoff data and five days antecedent rainfall-runoff using the median, geometric mean, and standard asymptotic fit procedures.

Curve Number Estimation

The CN values corresponding to the catchment soil types, land cover and land management conditions can be selected from the NEH-4 tables. The CN value of AMC II (CNII) was provided by the SCS-CN manual and the CN value of AMC I (CNI) and CN value of AMC III (CNIII) can be calculated by applying the (USDA SCS, 1985) equations (USDA SCS, 1985). CNI, CNII and CNIII values for Ozat catchment were computed 64.46, 81.20 and 90.85 respectively based on land used, soil characteristics and previous 5-days rainfall of the catchment.

When rainfall-runoff data are available for a watershed, *P* and *Q* pairs are used directly to determine the potential retention S characterizing the watershed (Chen 1982) as:

$$S = \frac{P}{\lambda} + \frac{(1-\lambda)Q - \sqrt{(1-\lambda)^2 Q^2 + 4\lambda PQ}}{2\lambda^2} \tag{06}$$

CN value can be directly calculated from rainfall-runoff data by substituting value of *S* in Eq. (05) and rearranging it as:

$$\mathrm{CN} = \frac{25400}{\frac{P}{\lambda} + \frac{(1-\lambda)Q - \sqrt{(1-\lambda)^2 Q^2 + 4\lambda PQ}}{2\lambda^2}} + 254 \tag{07}$$

The median CN is computed by finding the median of the curve numbers of selected events from the calibration period (1980 to 1994). The curve numbers for events are computed using Eq. (06) and Eq. (07). The median CN as calculated from rainfall and runoff depths associated with the daily runoff events appears to have been the source of the original handbook table values. This procedure has the benefits of simplicity, precedent, and consistency with existing tables. However, it requires long records (one observation per year) and is incapable of capturing short term or transient effects, such as a fire or changes in agronomic practices (Hawkins 2010).

The (NRCS, 2001) uses the geometric mean to determine a watershed curve number if the values calculated from rainfall and runoff measured for each event are log normally distributed (Yuan 1933). Yet, no one seems to have established the log-normality of curve number distributions. The major strength of the geometric mean is quantification of uncertainty with the standard deviation and confidence intervals. The normal distribution describes many random processes but it generally does not provide satisfactory fit for flood discharge and other hydrologic data (Prasuhn 1992). Though, the normal distribution is not well suited to hydrologic data, the related distribution; the lognormal distribution works reasonably well (Prasuhn 1992). The geometric mean is obtained by finding the arithmetic mean of the series $\overline{\log S}$; and then estimating the geometric mean maximum potential retention$10^{\overline{\log S}}$. The curve number is then computed using Eq. (08):

$$CN = \frac{100\,\alpha}{\alpha + 10^{\overline{\log S}}} \tag{08}$$

Where α = 254 mm (10in).

In standard asymptotic fit method, *P* and *Q* data are re-aligned on a rank-order basis, creating a new set of *P*: *Q* pairs (ordered *P*: *Q* data). This is done by rank ordering the rainfalls and runoff separately, and reassembling them as rank-ordered pairs. These *P*: *Q*pairs have equal return period and not necessarily associated with the original rainfall *P*. (Sneller 1985) and (Hawkins 1993) identified three types of watershed responses (standard, violent, and complacent). The Standard response was observed in Ozat catchment and to be described by the following:

$$CN(P) = CN_\infty + (100 - CN_\infty)e^{(-kP)} \tag{09}$$

Eq. (09) has the algebraic structure of the Horton infiltration equation. In the standard response, the curve number as a function of rainfall *P* (CN [*P*]) decreases to an asymptotic constant CN_∞ with *k* (the fitting coefficient or rate constant in the units of 1/*P*) that describes the curve number approach to the asymptotic constant CN_∞. Optimized values of CN_∞

and k are obtained by fitting Eq. (09) using least-squares procedure. The recent report to NRCS (Woodward et al. 2010) recommends this procedure as the preferred technique for CN parameterization. CNs values determined by different methods and optimised values of parameter CN_∞ and k for $\lambda = 0.05$, $\lambda = 0.10$ and $\lambda = 0.20$ are presented in Table 1.

Curve Number Estimation Based on Five Days ARC

The CNs based on five days antecedent rainfall-runoff data of fifteen years period (1980-1994) are calculated using median method and geometric mean method. In asymptotic fit method, optimized values of parameters $CN_\infty$and k are computed using five days antecedent ordered P-Q data. CNs values are then determined by incorporating mean annual rainfall amount of calibration period (1980-1994) 752.30 mm, CN_∞ and k in Eq. (09).Table 1 presents estimated CNs values by different methods and optimised values of parameter CN_∞ and k for $\lambda = 0.05$, $\lambda = 0.10$ and $\lambda = 0.20$ using five days ARC.

In stream flow separation, the most frequently used methods are filtering separation method and statistical method (Frequency-Duration analysis). In filtering separation method, base flow separates from the stream flow time series data by processing or filtering procedure. Although these methods don't have any physical basis it aims at generating an objective, repeatable and easily automated index that can be related to the base flow response of the catchment (Arnold et al. 2000). In this study the (Nathan and McMohan 1990) filtering method is used to separate base flow from stream flow.

$$Q_{d(i)} = \alpha Q_{d(i-1)} + \beta(1+\alpha)(Q_{T(i)} - Q_{T(i-1)}) \tag{10}$$

Where,

Q_d= Direct flow part of the stream flow which is subjected to $Q_d \geq 0$ for the time i in days

Q_T = Total flow (i.e base flow + direct flow)

α = a coefficient with value 0.925

β = a coefficient with value 0.5

STATISTICAL CRITERIONS

In this study, the simulated performances of SCS-CN method with CNs values determined by daily rainfall-runoff data and five days ARC data using three CN determination procedures, viz, the median, geometric mean and standard asymptotic fit are evaluated using two popular statistical criterions refined Willmott's index (d_r) (Willmott et al. 2012) (Dimensionless statistic) and mean absolute error (MAE) (error index statistic). Dimensionless techniques provide a relative model evaluation assessment, and error indices quantify the deviation in the units of the data of interest (Legates and McCabe 1999). These statistical criterions are used to measure the agreement between predicted and observed values of event runoff. To check precision and correctness of the methods, (d_r) is applied. The MAEdoes not tell about degree of error but it is used for the quantitative analysis of residuals.

The d_r is applied to quantify the degree to which values of observed runoff are captured by the models. The range of d_r is from -1.0 to 1.0. A d_r of 1.0 indicates perfect agreement between model and observation, and a d_r of -1.0 indicates either lack of agreement between the model and observation or insufficient variation in observations to adequately test the model.

The root mean square error (RMSE) and MAE are both error measures used to represent the average differences between models predicted and observed values. It is importantto include absolute error measures (such as MAE and RMSE) in a model evaluation because they providean estimate of model error in the units of the variable (Legates and McCabe 1999). The MAE provides a more robust measure of average model errorthan the RMSE, since it is not influenced by extremeoutliers A higher MAE value indicates poor model performance and vice versa. MAE = 0 indicates a perfect fit. MAE is the most natural and unambiguous measure of average error magnitude.

CNs values are determined by daily rainfall-runoff data and five days ARC using all the three procedures for Ozat catchment. The performances of SCS-CN method with different CNs values are evaluated using selected statistical criterions. The resulting values of d_r, and MAE are presented in Table 2.

RESULTS AND DISCUSSIONS

The SCS-CN method was applied to the data set of Ozat catchment with CNs values estimated by median, geometric mean and standard asymptotic fit procedures. The data set of 15 years (1980-1994) was used to determine CNs from daily rainfall-runoff data and five days ARC while the data set of 16 years (1995-2010) was used for simulation. Table 2 displayed the results of simulated performance of SCS-CN method with different CNs and λ values.

CNs depends largely on the soil type and antecedent moisture condition. This antecedent moisture means the average moisture condition. Impact of CNs determined by using five days ARC wasexamined in this study.Table 1 showed that estimated CNs by all the three methods had direct relationship with $\lambda$for both types of data set. Lower CNs were found when five days ARC data set was used in place of daily rainfall-runoff data set.CNs were found in range from 58.78 to 85.52 for daily rainfall-runoff data set and from 42.2 to 73.75 for five days ARC data set. The comparison between computed CNs values for λ=0.20 and tabulated CN values (64.46 to 90.85) indicated that computed CNs were slightly in a narrow range and had higher extreme CNs values. Hence, original SCS-CN method tends to overestimate CN and thus runoff in such semi-arid region. All three methods were estimated the highest Curve number values for λ = 0.20.Median procedure computes higher CNs than geometric mean and standard asymptotic fit methods. The optimized parameter CN_∞values exhibited direct relationship while parameter k values showed inverse relationship with CNs and λ.CN_∞ values are decreased with increment in k values.

The results indicated that performance of SCS-CN method was improved when CNs estimated based on five days ARC data set instead of daily rainfall-runoff data set (Table 2). Improvement in performance of SCS-CN method was observed on application of five days ARC for all three methods of CNs determination. In Median procedure, the d_r and MAE were between 0.04 and 0.27 and 1.47 mm and 1.89 mm, respectively for daily rainfall-runoff data while the d_r and MAE were between 0.37 and 0.45 and 1.07 mm and 1.20 mm, respectively for five days ARC data. In geometric mean procedure, the d_r and MAE rangingfrom 0.14 to 0.37 and 1.24 mm to 1.68mm respectively were improved ranging from 0.35 to 0.48 and 1.02 mm to 1.24 mm, respectively when five days ARC data replaced with daily rainfall-runoff data. The d_r ranging from 0.47 to 0.49 was modified to 0.58 constant value while the MAE ranging from 1.13 to 1.18 was improved ranging from 0.93 mm to 0.94 mm on application of five days ARC in standard asymptotic fit method. The standard asymptotic fitmethodwas produced comparatively more realistic results with d_r = 0.58 and MAE = 0.93 mm for λ = 0.05 and λ = 0.10. As compare to the standard asymptotic fit method, other two methods are poor in goodness of fit criteria and produced results with marginally larger errors. For λ = 0.05, the SCS-CN model had a good performance in simulation for the study area. These results were in good agreement to the other studies (Hawkins et al. 2002;

Woodward et al. 2003; Descheemaeker et al. 2008; Hawkins et al. 2009; Shi et al. 2009; D'Asaro and Grillone 2010, 2012; Fu et al. 2011). Figures 2 to 7 presented the simulated performance of SCS-CN method with CNs values estimated by all three methods using both types of data setfor λ = 0.05 on monthly time scale.

SUMMARY AND CONCLUSIONS

In the present study, impact of daily rainfall-runoff data set and five days antecedent rainfall-runoff data set on performance of the SCS-CN method is examined by applying the SCS-CN method with CNs determined by median, geometric mean and asymptotic fit procedures to Ozat catchment of India.

The following conclusions can be drawn from this study:

- The CNs values increase with increment in initial abstraction ratio λ from 0.05 to 0.20.
- Five days ARC data set is produced lower CNs values than that of daily rainfall-runoff data set.
- The CNs values computed from median procedure are higher than the CNs values computed from geometric mean procedure and asymptotic fit procedure.
- The SCS-CN method is performed well with λ = 0.05 for Ozat catchment.
- Highest CN = 85.33 is computed by median procedure with daily rainfall-runoff data set for λ = 0.20.
- The simulated performances of the SCS-CN method are improved on application of five days antecedent rainfall-runoff data set.
- Little variation is found in d_r and MAEfor λ = 0.05, 0.10 and 0.20 in performance of SCS-CN method with standard asymptotic fit procedure.
- Positive correlation is observed between λ and parameter CN_∞ while negative correlation is observed between λ and fitting parameter *k.*
- The lowest values of parameters CN_∞ and *k* are found for λ = 0.05 and λ = 0.20 respectively.

Consideration of all the results from the analysis and evaluation indicate that the relatively best performance is observed in SCS-CN method (d_r = 0.58 and MAE = 0.93 mm) when it is used with CNs determined by Standard asymptotic fit and five days antecedent rainfall-runoff data set. It is evident from the above evaluations that improvement in the predictive capability of SCS-CN method is possible by the use of five days antecedent rainfall-runoff data set for the Ozat catchment.

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APPENDICES

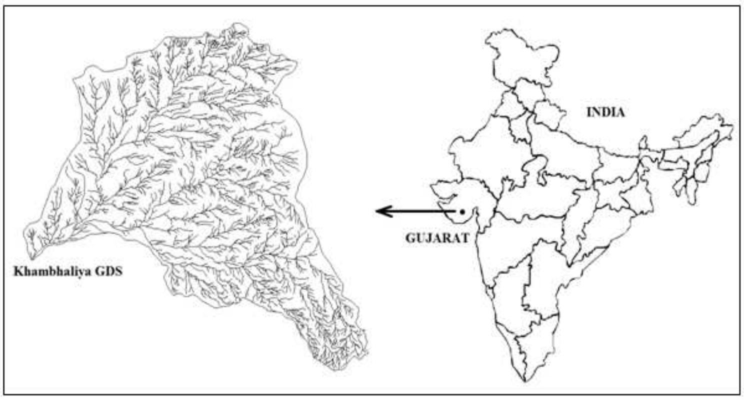

Figure 1: Digitized 6th Order Drainage Network Map of Ozat Catchment

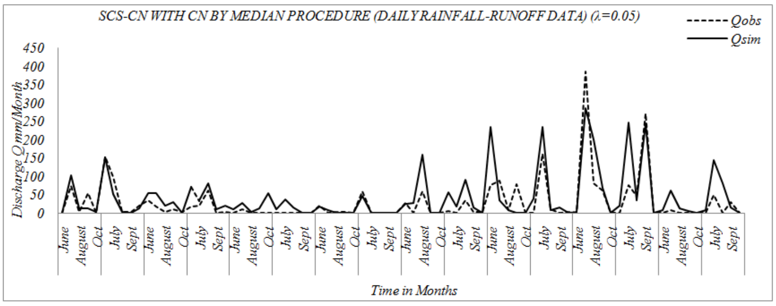

Figure 2: Simulated Performance of SCS-CN Method with CN by Median Procedure and Daily Rainfall-Runoff Data on Monthly Time Scale

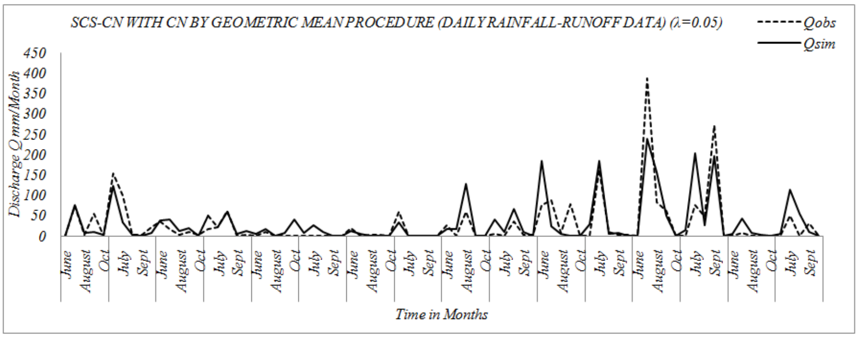

Figure 3: Simulated Performance of SCS-CN Method with CN by Geometric Mean Procedure and Daily Rainfall-Runoff Data on Monthly Time Scale

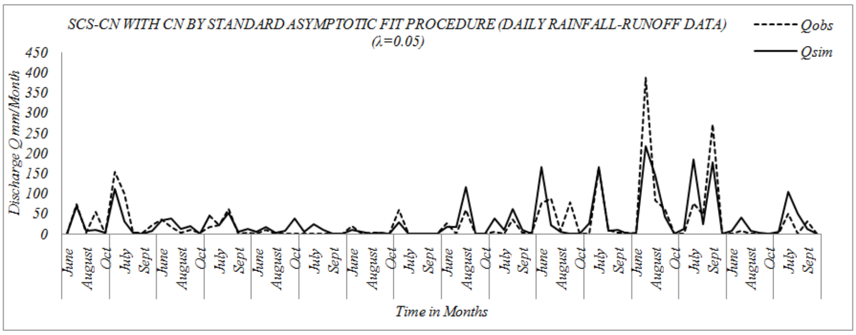

Figure 4: Simulated Performance of SCS-CN Method with CN by Standard Asymptotic Fit Procedure and Daily Rainfall-Runoff Data on Monthly Time Scale

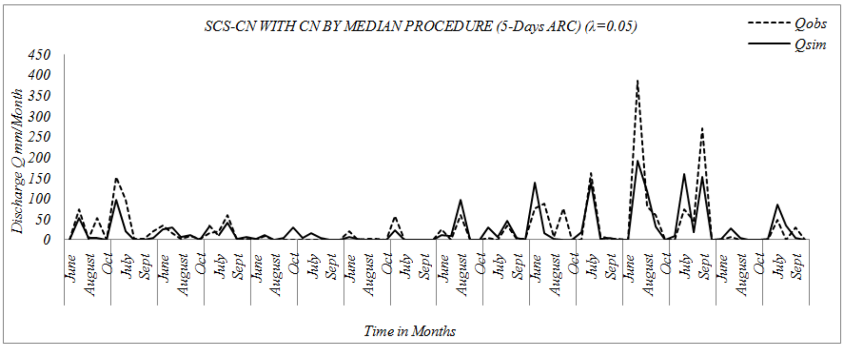

Figure 5: Simulated Performance of SCS-CN Method with CN by Median Procedure and 5-Days ARC on Monthly Time Scale

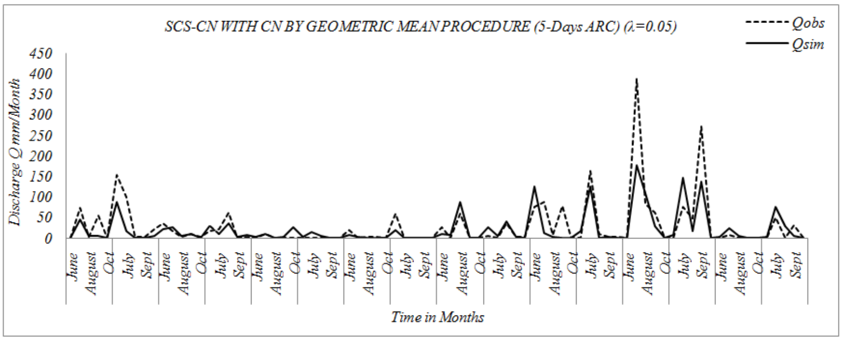

Figure 6: Simulated Performance of SCS-CN Method with CN by Geometric Mean Procedure and 5-Days ARC on Monthly Time Scale

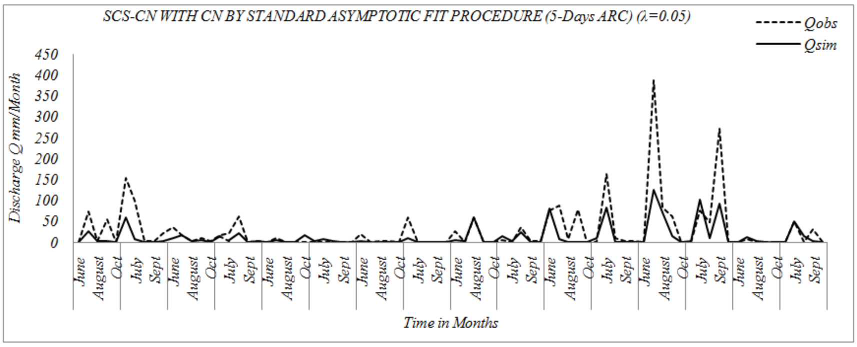

Figure 7: Simulated Performance of SCS-CN Method with CN by Standard Asymptotic Fit Procedure and 5-Days ARC on Monthly Time Scale

Table 1: CNs Values Determined by Different Procedures

CNs Values Determined for Different λ Values Using Daily Rainfall-Runoff Data					
	Median	Geometric Mean	Standard Asymptotic Fit		
λ	CN	CN	CN	CN_∞	K in mm^{-1}
0.05	70.05	62.10	58.78	58.45	0.10
0.10	78.50	73.20	63.52	61.41	0.06
0.20	85.33	82.52	70.67	63.25	0.03
CNs Values Determined for Different λ Values Using Five Days Antecedent Rainfall-Runoff Data					
	Median	Geometric Mean	Standard Asymptotic Fit		
λ	CN	CN	CN	CN_∞	K in mm^{-1}
0.05	53.90	50.85	42.20	40.64	0.07
0.10	62.32	62.48	51.06	44.39	0.04
0.20	72.44	73.75	63.81	47.44	0.02

Table 2: Simulated Performance of SCS-CN Method Using CNs Values Determined by Different Procedures

CNs Values Determined by Daily Rainfall-Runoff						
	Median		Geometric Mean		Standard Asymptotic Fit	
λ	d_r	MAE in mm	d_r	MAE in mm	d_r	MAE in mm
0.05	0.27	1.47	0.37	1.24	0.47	1.18
0.10	0.15	1.68	0.27	1.44	0.48	1.16
0.20	0.04	1.89	0.14	1.68	0.49	1.13
CNs Values Determined by Five Days Antecedent Rainfall-Runoff						
	Median CN		Geometric Mean CN		Standard Asymptotic Fit	
λ	d_r	MAE in mm	d_r	MAE in mm	d_r	MAE in mm
0.05	0.45	1.07	0.48	1.02	0.58	0.93
0.10	0.42	1.11	0.42	1.12	0.58	0.93
0.20	0.37	1.20	0.35	1.24	0.58	0.94